Integrating Two-Dimensional Nanomaterials and Molecular Dielectrics for Radiation-Hard Non-Volatile Memory

Completed Technology Project (2012 - 2016)

Project Introduction

The space radiation environment presents a significant hazard to the critical electronic components used in a variety of space applications. Many such applications require data storage solutions that provide high storage capacities while abiding strict power consumption limitations. Specifically, the need for radiation-hard non-volatile memories is a long-standing problem in the space community. The proposed work describes a progression toward a radiation-hard, high performance non-volatile memory device by implementing principles from terrestrial memory technology using two-dimensional nanomaterials with proven radiation hardness. Graphene, consisting of a single-atom thick hexagonal carbon lattice, has been shown to exhibit a number of superlative qualities as a nanoelectronic material for many applications. Perhaps most relevantly, graphene has recently been incorporated as the floating gate (FG) layer of a flash memory cell, resulting in improved device performance. Single layer MoS(2) is a three-atom thick material that shares many of the desirable electronic qualities of graphene. In addition, MoS(2) thin-film transistors (TFTs) have demonstrated superior switching capability compared to graphene. These qualities make MoS(2) an exceptional candidate as a channel material for a FG flash memory device. Finally, self-assembled nanodielectrics (SANDs) are a unique class of hybrid organic/inorganic dielectric thin films that boast low leakage current and high dielectric constant. The integration of SANDs with graphene and many other low dimensional nanomaterials has demonstrated improved TFT device performance compared to traditional gate dielectric materials. Initial tests suggest SANDs are hard to ionizing radiation, and the total ionizing dose (TID) response of graphene has been studied, resulting in strong evidence that graphene is TID-hard as well. By analogy to the two-dimensional structure of graphene, MoS(2) is likely to be TID-hard as well. As long-term TID effects are the primary concern in a FG flash memory cell, the incorporation of graphene, MoS(2), and SANDs into a FG flash memory device holds promise for a radiation-hard nonvolatile memory. This integration will require that that SANDs be deposited atop graphene and MoS(2). Existing variants of SANDs are presently deposited only on SiO(2) terminated surfaces, limiting thin-film transistor devices to those having a global back gate geometry on a Si wafer. Moreover, deposition of ultrathin oxide materials on graphene (and possibly MoS(2)) has historically proven problematic, as its surface chemistry impedes the deposition of uniform, high quality dielectric films. Recently, the Hersam Laboratory has developed a fabrication scheme that uses a self-assembled organic seeding layer to facilitate the deposition of ultrathin, conformal oxide materials on graphene via atomic layer deposition (ALD). The extension of this scheme to the vapor deposition of SANDs on graphene and MoS(2) represents a significant challenge that will necessitate the development of a new SAND material and deposition process that is compatible with ALD. Overall, the proposed device structure motivates the following research objectives: Development of a novel SAND variant that is compatible with atomic layer deposition. Integration of SAND on graphene by deposition on organic

Project Image Integrating Two-Dimensional Nanomaterials and Molecular Dielectrics for Radiation-Hard Non-Volatile Memory

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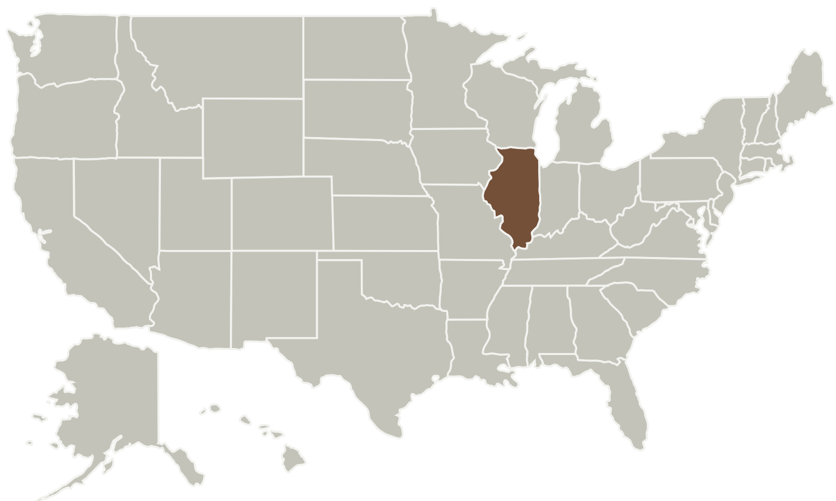
self-assembled monolayers. Integration of SAND on MoS2 by deposition on organic self-assembled monolayers. Complete assembly and testing of MoS(2)/SAND/graphene FG flash memory device.

Anticipated Benefits

As long-term TID effects are the primary concern in a FG flash memory cell, the incorporation of graphene, MoS(2), and SANDs into a FG flash memory device holds promise for a radiation-hard nonvolatile memory.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Northeastern University(NEU)	Supporting Organization	Academia	Boston, Massachusetts

Primary U.S. Work Locations
Illinois

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

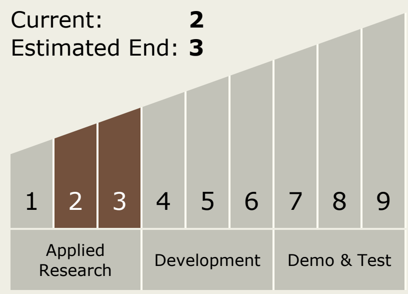
Mark Hersam

Co-Investigator:

Julian Mcmorrow

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Images

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Project Image Integrating Two-Dimensional Nanomaterials and Molecular Dielectrics for Radiation-Hard Non-Volatile Memory
(https://techport.nasa.gov/image/1783)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Areas

Primary:

- TX02 Flight Computing and Avionics
  - └─ TX02.1 Avionics Component Technologies
    - └─ TX02.1.1 Radiation Hardened Extreme Environment Components and Implementations